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硕士学位论文

脉冲掺铥光纤激光器理论研究及其石墨烯可饱和吸收体研制

Theoretical Study on Pulsed Tm-doped Fiber Laser and Preparation of Its Graphene-based Saturable Absorber

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摘要

双包层光纤激光器相比传统的固体激光器结构紧凑、散热性良好、光束质量高等优点，目前已经广泛应用于通信、工业加工等诸多领域。双包层掺铥光纤激光器输出波长在 2 微米附近，处于人眼安全波段。是一种极具发展潜力的中红外光源。石墨烯是一种近年来快速发展的二维纳米材料，石墨烯在很宽的波长范围内具有优良的可饱和吸收性能，将石墨烯作为可饱和吸收器件，与双包层掺铥光纤激光器结合有望得到性能良好的被动调 Q 脉冲输出。围绕基于石墨烯的掺铥光纤激光器被动调 Q，本文进行了理论和实验研究，主要的工作内容和创新点概括如下：

建立较为完整的、光纤激光器通用的行波模型，涵盖了线型腔、环形腔结构的光纤激光器，通过动态边界条件将续波（CW）、主动/被动调 Q 集中到了同一个模型中去，该模型相比传统的点模型理论精度有了很大提高。基于有限差分理论，推导出了模型的算法。并采用 C/C++将算法实现。

讨论了光纤激光器的扰动因素，首次建立了含有随机扰动项的掺铥光纤激光器行波模型。通过数值求解随机偏微分方程组，分析了激光器受到扰动后的稳定性，补充了传统的弛豫振荡理论。

通过数值计算，研究了掺铥光纤激光器调 Q 脉冲输出的特性。研究了主动调 Q 多脉冲峰的现象。首次理论预言了主动调 Q 的掺铥光纤激光器也会存在主脉冲峰劈裂的现象，并对此现象给出了理论解释。论述了石墨烯可饱和吸收的物理过程，建立了描述石墨烯可饱和吸收的速率方程，首次采用行波模型研究了基于石墨烯的掺铥光纤激光器被动调 Q 输出特性。

通过端面耦合，制备了石墨烯锁模器，利用掺镱激光测试了多种石墨烯的可饱和吸收性能。

尝试采用等离子体溅射沉积碳制备石墨烯，但是未获成功，对沉积到的碳膜提出了一种潜在的应用方向。

关键词：掺铥激光；行波模型；石墨烯

Abstract

Comparing to the traditional solid-state lasers, double-cladding fiber lasers (DCFLs) have many advantages such as fine compactness, good beam quality, easy to cooling and so on. The good properties of DCFLs make them promising laser source and widely apply to broad area such as communication, machining, medical treatment and so on. The Tm-doped DCFLs working at about 2μm, which is within the eye-safe band, have attracted many attentions. It is a potential light source for mid-infrared. Graphene is a newly found 2-dimetional crystal, and a good saturable absorber in wide band. The graphene-based passively Q-switched Tm-doped DCFLs were expected to generate pulses with fine properties. In this thesis, the theoretical and experimental works were done for the graphene-based passively Q-switched Tm-doped DCFLs.

The general numerical model based on the travelling wave equation was built up for fiber lasers, in which the ring-cavity and linear-cavity with CW, actively/passively Q-switched output were taken into account. The algorithm for the general model was derived based on the finite difference method. The algorithm was implemented by C/C++ language, and visualized by VC6.0.

The disturbance in Tm-doped DCFLs was discussed. A model with random disturbance for Tm-doped DCFLs was set up. By solving the model numerically, the stability of Tm-doped DCFLs was investigated. The results could rich the traditional relaxation oscillating theory significantly.

The characteristics of Q-switched pulses from Tm-doped DCFLs were studied. For actively Q-switching, the regular pattern of multi-peak was concluded. The mechanism of peak-split was proposed. The peak-split was predicted to appear in actively Q-switched Tm-doped DCFLs. The mechanism of saturable absorption in graphene was discussed, and the rate equation for it was built up. The characteristics of graphene-based passively Q-switched Tm-doped DCFLs were studied.

The saturable absorption of three different sorts of graphene was tested with a

mode-locked Yb-doped fiber laser.

Preparing graphene via physical vapor deposition was tried. The trial was failed, but a potential application for the deposited carbon thin film was proposed.

Key words: Tm-doped lasers; travelling wave model; graphene

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